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DDT OF ALUMINUM/AIR MIXTURES IN A TUNNEL

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Abstract

The turbulent mixing behind the Deflagration-to-Detonation Transition (DDT) of Aluminum-Air mixtures is investigated using robust, adaptive two-phase numerical simulations. A recently proposed ignition model[1] that employs the use of empirical data for ignition delay time is used to model the burning characteristics of Aluminum particles. For a 500 g/m^3 Aluminum concentration in ambient air, the gas temperature profiles at different times are presented in Fig. 1. As evident from the scale of the turbulent eddies, the turbulent fluctuation levels are significantly enhanced behind the leading shock wave due to the energy release from detonation. Further downstream, however, the turbulence intensity decays, as evident from the presence of large scale structures, including also the presence of large Kelvin-Helmholtz instabilities (refer to Fig. 1). The instantaneous pressure field, shown in Fig. 2 (a), identifies the leading shock and the transverse waves, whose interaction leads to the production of vorticity. Furthermore, pockets of unburned fuel are also carried downstream, which are colder and so never burn to completion. This is evident from the blue/green spot observed in the downstream region in Fig. 2 (b). The vorticity profile, shown in Fig. 2 (c), and the baroclinic term, shown in Fig. 2 (d), identify that the regions of vorticity production are more prominent in the heat release regions immediately behind the leading shock wave, and slowly fade away in downstream regions. This shows that the exothermic energy release plays a significant role in the production of turbulence/vorticity behind the detonation wave. In numerical simulations of the DDT phenomena, the use of a fine grid resolution is indispensable in order to capture all the important scales of relevance in the reaction and the turbulent zone. To the best of the authors' knowledge, the present simulations employ the finest ever grid used for 3D simulations of two-phase DDT. Oran and others[2,3] have undertaken robust 3D simulations of gaseous DDT with very fine grids and have elucidated the physics of the flow-field behind the leading detonation wave; however, for two-phase DDT, such fine grid simulations have not been used before. For two-phase DDT, Hayashi[4] and Veyssiere[5] have performed either 2D simulations with a similar grid resolution, or have carried out 3D simulations with a poorer grid resolution. In the final paper we will also investigate the grid resolution essential for accurately predicting DDT in Aluminum-air mixtures. This research effort will also investigate the intensity of turbulent mixing in the DDT of Aluminum-air mixtures for different Aluminum concentrations—lean, stoichiometric and rich. Finally, we will also study whether the turbulent mixing intensity behind the leading detonation wave will attain a self-similar character with time, which is hitherto an unsolved issue for two-phase DDT.

Acknowledgements

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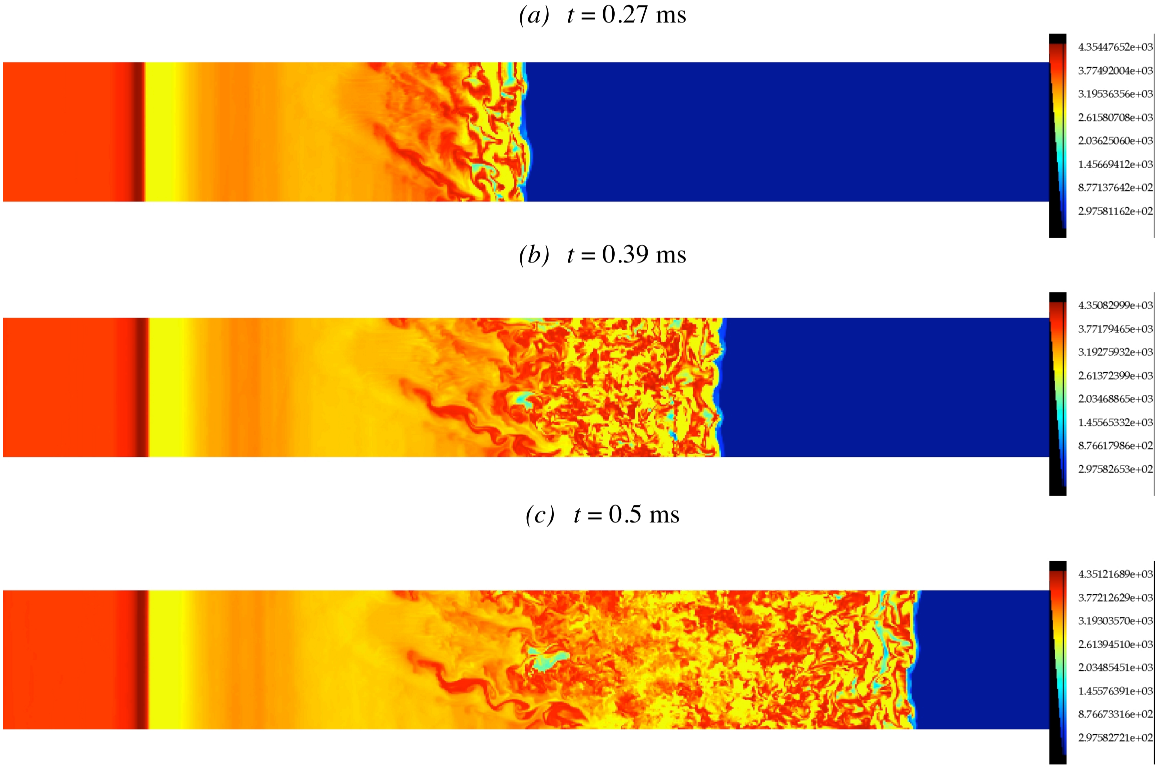

Figure 1. Cross-sectional view of gas temperature in the detonation field in the tunnel.

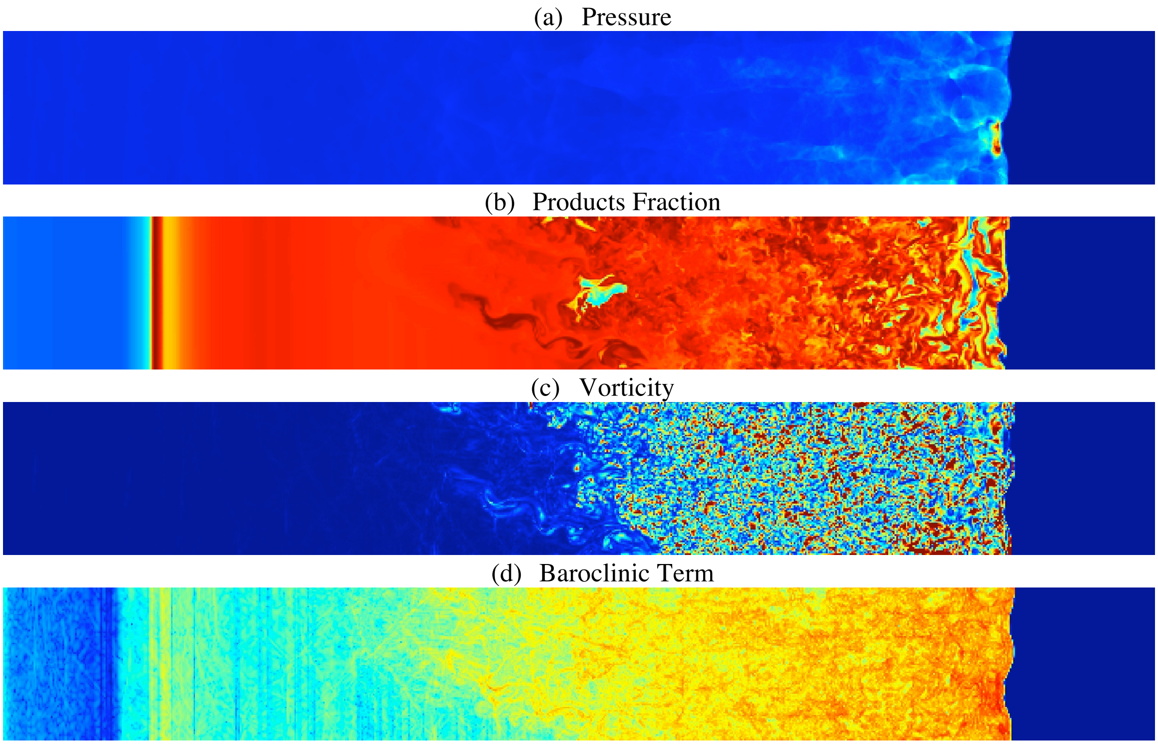

Figure 2. Cross-sectional view of variables in the detonation field in the tunnel at 0.5 ms.